The Science Behind In-Vessel Composting

Danielle Aslam, M.S.
Integrated Waste Management Specialist
California Integrated Waste Management Board
Local Assistance and Market Development Division

INTEGRATED WASTE MANAGEMENT BOARD

What will be covered:

- In-Vessel Composting Definition
- Aerobic and Anaerobic Decomposition
- In-Vessel Composting Process
- Advantages and Disadvantages of In-Vessel Composting
- Types of Vessels
- Odor and Leachate Management

What is In-Vessel Composting?

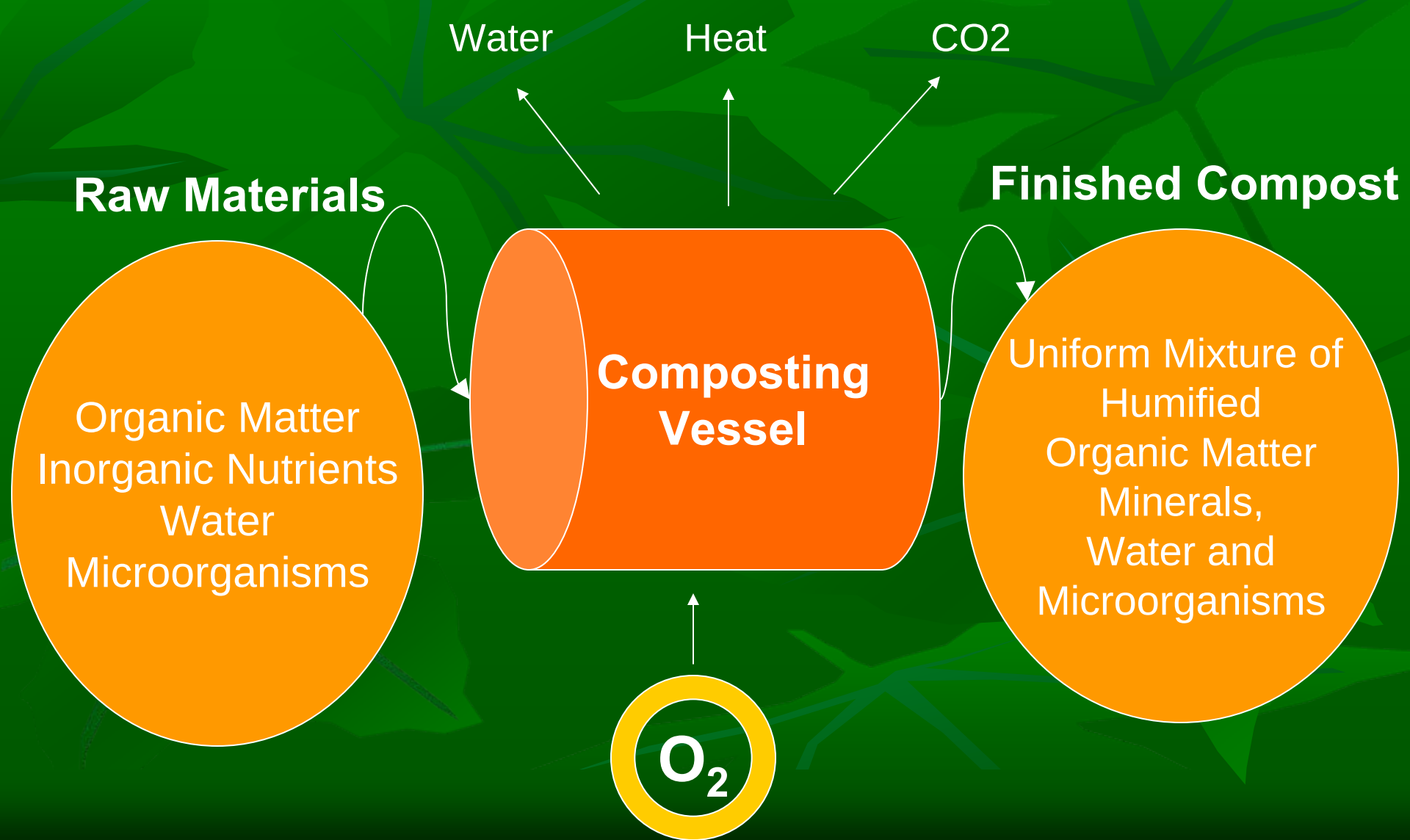
- "a process in which compostable material is enclosed in a drum, silo, bin, tunnel, reactor, or other container for the purpose of producing compost, maintained under uniform conditions of temperature and moisture where air-borne emissions are controlled" – Title 14 CCR, Division 7, Chapter 3.1, Section 17852
- Uses forced aeration and/or mechanical agitation to control conditions and promote rapid composting
- Each system design is different, but there are some common elements.

Two Types of Decomposition

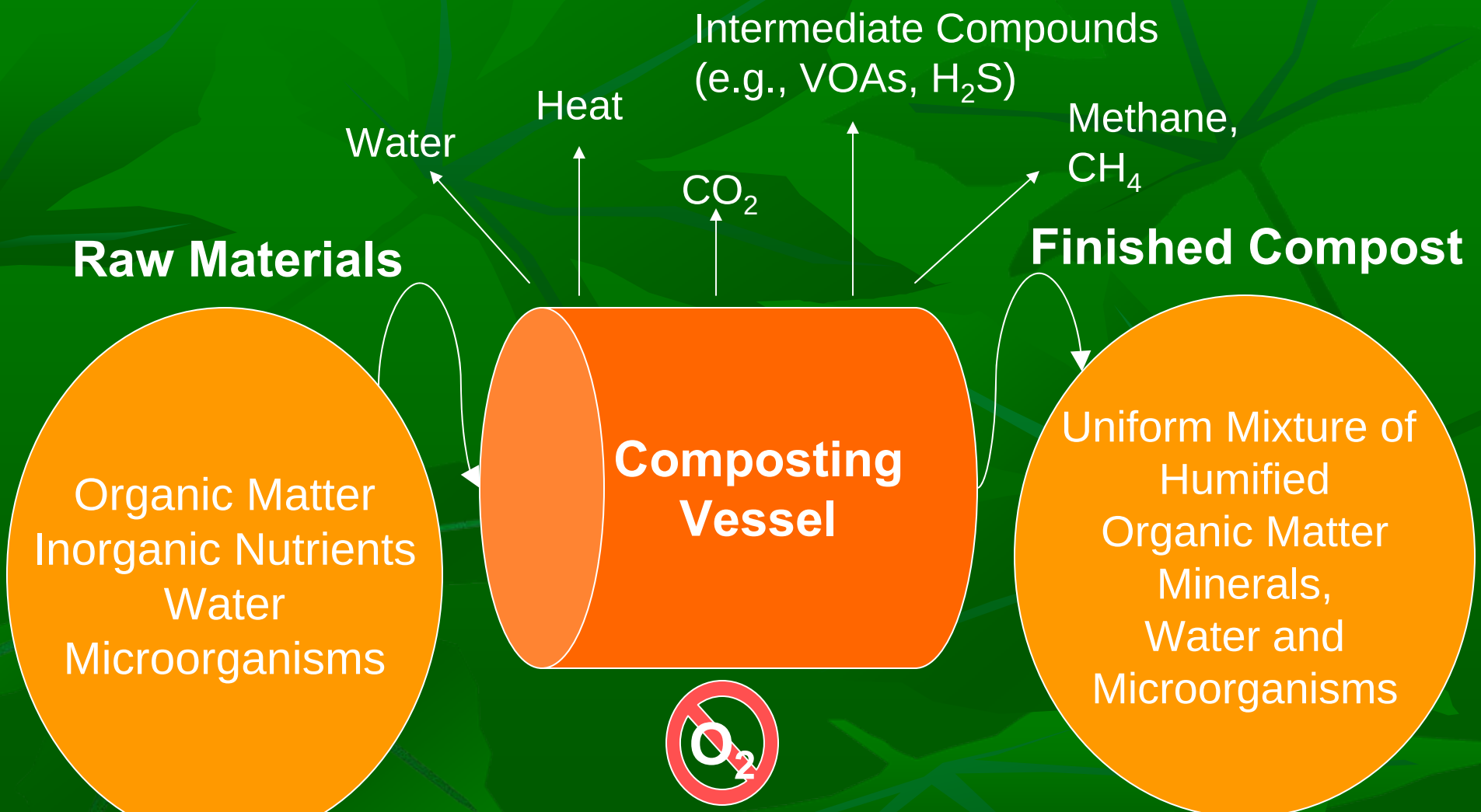
- Aerobic – Biological decomposition of organic substances in the presence of oxygen

- Anaerobic –Biological decomposition of organic substances in the absence of oxygen

Aerobic Composting



Anaerobic Composting



❖Methane and other greenhouse gases can be trapped and used for fuel (anaerobic digestion)

Aerobic vs. Anaerobic Composting

- In general, aerobic composting is done in the U.S. because it:
  - Reaches optimal temperatures faster
    - Leads to faster decomposition
    - Moves material through the vessel quickly
- Degrades and prevents the formation/emission of odorous compounds which are produced under anaerobic conditions (e.g., hydrogen sulfide and short-chain fatty acids).

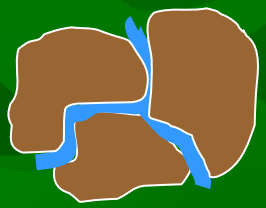
Aerobic vs. Anaerobic Composting

- Reasons one might do anaerobic composting
  - It does not require aeration or turning
  - It can retain more nitrogen and initial organic matter
  - Greenhouse gases can be trapped and harvested for energy
- We will assume aerobic composting for the rest of the presentation.

- Important: Even in aerobic composting there will be pockets of anaerobic activity caused by excess moisture, inadequate porosity, rapid degradation and large pile size

In-Vessel Composting Steps

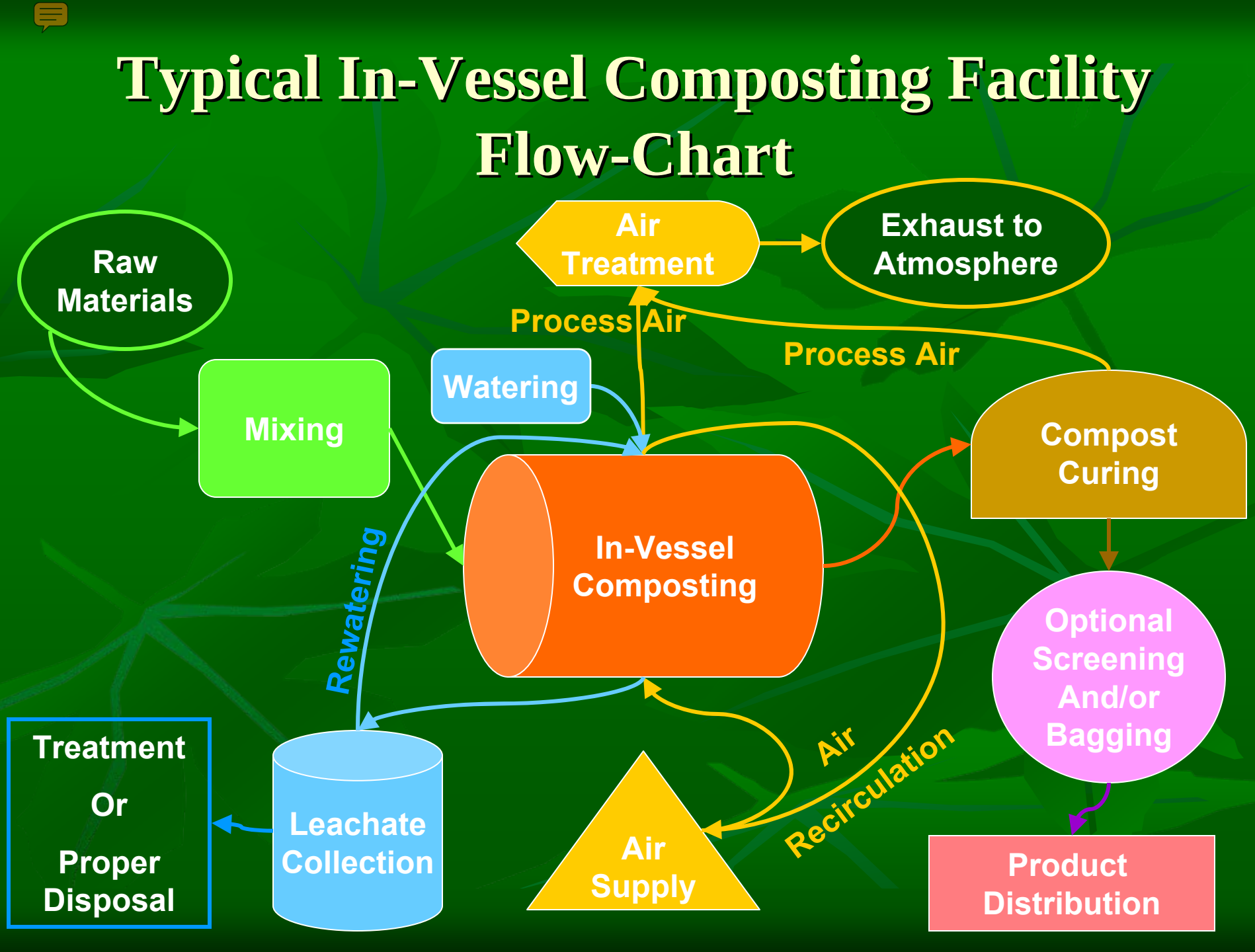
1) Raw materials (Feedstock) mixing
   - Optimize mixture for porosity, particle size, moisture, carbon to nitrogen ratio, substrate complexity and quality
   - Often done before placing in vessel



2) Active composting in the vessel
   - High temperatures (mostly thermophilic), rapid decomposition and high odor potential.
   - Where pathogens and weed seeds are killed
   - Generally 2-3 weeks, but could be shorter or longer

3) Curing
   - Ending stage after microbial activity begins to stabilize and pile cools (mesophilic)
   - Can be inside the composting vessel, in a separate vessel, or outside in windrows or aerated static piles
   - Odorous compounds are not usually produced
   - Generally cured for at least 30 days

Typical In-Vessel Composting Facility Flow-Chart



Benefits of Cured Compost

1) Increases soil's structure and ability to hold water and nutrients
2) Can reduce the need for pesticides by increasing soil biological activity
3) Offsets use of natural resources (e.g., peat moss) for mulch
4) Diverts valuable organic materials from landfills
5) Adds organic matter and nutrients to soil, reducing the need for chemical fertilizers.
6) Encourages slow release of nitrogen and lowers the carbon to nitrogen ratio, making nitrogen more available to plants.
7) Kills pathogens and weed seeds
8) Prevents soil erosion.

Raw Materials Used

- Municipal Solid Waste (≈ 30% compostable)
- Municipal Sewage Solids (Biosolids)
- Manure
- Agricultural Crops and Food Wastes
- Industrial Waste
- Logging and Wood-Manufacturing Residues
- Miscellaneous Organic Waste

Active Composting In the Vessel

- Composting conditions are controlled using aeration and/or agitation to promote fast decomposition
  - Supplies optimal oxygen levels for aerobic activity (>10%), optimizes moisture content (40-60%), and controls temperatures in the optimal thermophilic range, where microbial efficiencies are the highest
  - To do this, aeration & agitation are controlled by temperature, moisture and/or oxygen feedback (typically temperature), or cycle timers
- Aeration systems can be negative or positive and have a variety of designs, but air should be evenly distributed
- Agitated systems also break up particles, which provides microorganisms better access to carbon for decomposition.

Aeration ducts at Inland Empire composting facility, http://www.ierca.org/process/compostprocess.html

Advantages of In-Vessel Composting

1) Composting can be more closely controlled, leading to faster decomposition and more consistent product quality.
2) Effects of weather are diminished
3) Less manpower is required to operate the system and staff is less exposed to composting material
4) Can often be done onsite, saving collection costs
5) Less land area is required
6) Process air and leachate can be more easily collected and treated
7) Public acceptance of facility may be better
8) Can accommodate various types and amounts of organic waste (e.g., odorous biosolids & food)

In-Vessel Composting Advantages

Disadvantages of In-Vessel Composting

1) High capital costs
2) Greater expense and skill required for operation and maintenance
3) Systems may need to be shut down due to odor problems, lack of available spare parts or for routine maintenance such as emptying
4) Capacity is limited by the size of the vessel
   - Although many systems are now modular for increased capacity

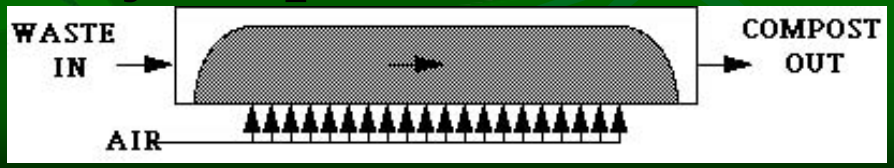
Types of Vessels Used

- Three main categories:
  - Enclosed Aerated Static Piles
  - Agitated Beds and Vessels
  - Rotating Drums

Types of Processing Within Vessels

- Batch – materials are processed at the same time, without introducing new feedstock

- Continuous – raw materials are loaded periodically, and are composted as they move through the system to the opposite end to be discharged
  - Usually only emptied for maintenance



Enclosed Aerated Static Piles

- Piles enclosed in a plastic bag, breathable fabric, ridged container or building
- Keep out moisture and control odors
- Use mechanical aeration to control compost conditions
- Not agitated

R.L. Spencer, “What’s new – In-Vessel Composting” BioCycle May 2007, Vol. 48, No. 5, p. 21

Jepson Prairie Organics Composting Facility in Dixon, CA

- Uses Ag-Bag Composting Technology
- Material is pushed into the bag as perforated aeration pipes are laid on the bottom of the bag
- Monitored for temperature and oxygen to ensure proper conditions

- Composts 5,200 tons of food scraps from San Francisco and Oakland and 2,000 tons of yard trimmings from Dixon and Vacaville every month.

- Material is composted in the bags for 60 days and then cured in open windrows for 30 days

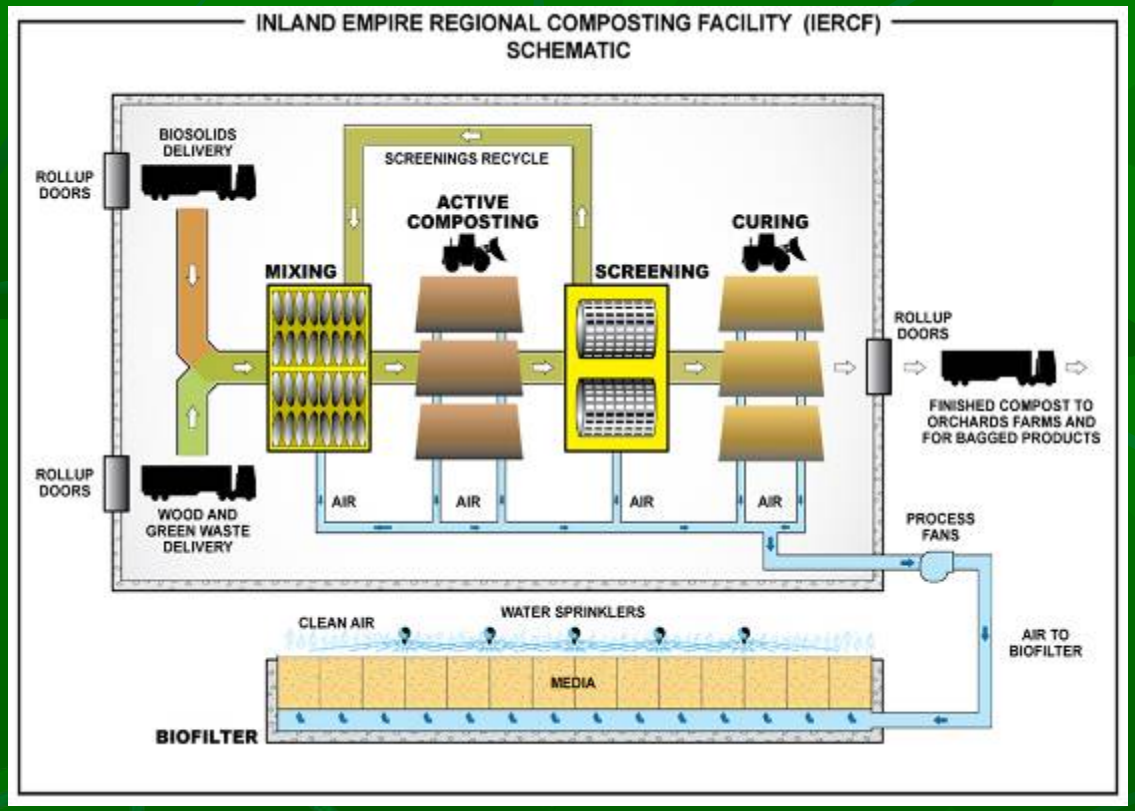
www.**jepsonprairieorganics**.com/

Mariposa County MSW Compost Facility

- Uses SV Composter™ Technology
- Eight vessels (14’ x 50’) with:
  - Automated aeration control and monitoring
  - In floor, plug-resistant aeration and air recirculation
  - Leachate collection and biofiltration of exhaust air
- Compost facility receives up to 50 tons unsorted MSW per day
  - Preprocessing is done to separate out the organic fraction for composting
  - Composted in the vessel for 16 days and cured in aerated static piles

http://www.compostsystems.com/pdfs/Mariposa_2006.pdf

Inland Empire Regional Composting Authority



- New composting facility in Rancho Cucamonga that completely encloses aerated static piles and other activities in a large building.
- Resulting from a partnership between the Inland Empire Utility Agency and the Los Angeles Sanitation District

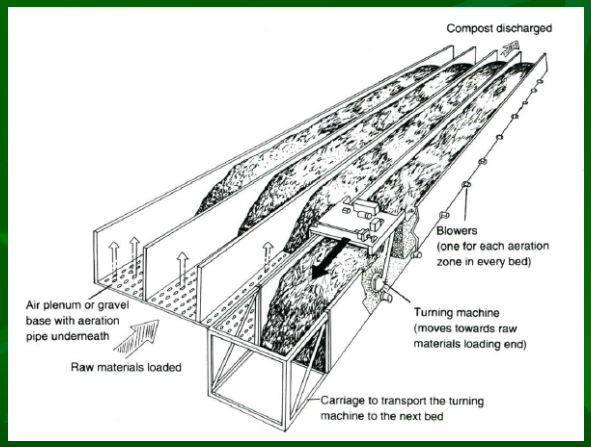
- Composts biosolids and other materials (manure, wood wastes, etc.) and uses biofilters to meet strict air quality standards.
- Uses continuous monitoring systems to optimize the compost manufacturing process and produce consistent quality compost.

http://www.ierca.org/process/compostprocess.html

Agitated Beds and Vessels

- Includes horizontal concrete bays with mechanical agitators that travel along the top, and horizontal or vertical vessels with an internal mixing device
- Have an optional conveyor belt for continuous systems
- Combine controlled aeration with periodic mixing

Source: Parsons, 2002



Source: Rynk 1992

Rancho Las Virgenes Composting Facility

•Facility in Calabasas that composts biosolids using the agitated bed system.

• They process about 70,000 gallons of biosolids per day and can handle up to 119,000 gallons.

• They began operation in 1994 and were the first in-vessel composting facility in Los Angeles County.

http://www.lvmwd.dst.ca.us

Some Agitated Vessel Systems

BioSystem Solutions' Vertical BioTower: Composts up to 20 tons per day, with automated loading, turning and compost discharge. Measures and controls temperature, oxygen and moisture content. Exhaust air is treated through a biofilter and leachate is captured for reuse.

http://www.biosystemsolutions.com/

HotRot Composting Systems: Enclosed, U-shaped vessel that aerates compost via tines attached to a central rotating shaft. Can process up to 14 tons daily input. It is programmable for controlling throughput and retention time and modular to accommodate expansion.

http://www.hotrotsystems.com/

Rotating Drums

- Cylindrical vessels that are automatically turned on a continuous basis, usually at speeds of 1 rpm or less.
  - Adapted from concrete or feed mixers and cement kilns
- Mix, grind and aerate materials to initiate composting
- Composting starts quickly – partly due to reduced particle size
- Usually have a very short residence time.
  - Can be said to be more physical than biological
- Can be partitioned for more controlled composting

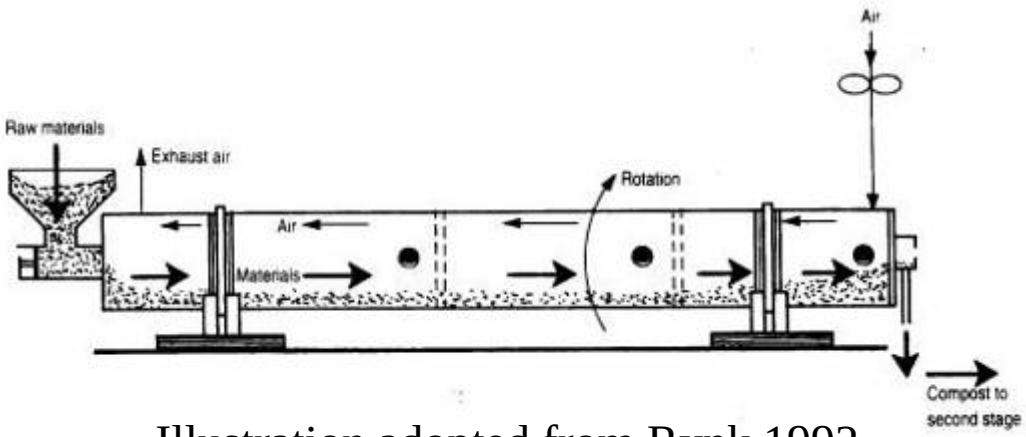


Illustration adopted from Rynk 1992

Some Rotating Drum Systems

Augspurger Engineering: Mobile, electrically powered drum that continuously processes up to 100 cubic yards at a time.

http://www.ciwmb.ca.gov/FoodWaste/Compost/InVessel.htm#Augspurger

B&W Organics: Continuously processes up to 96 cubic yards at a time. Moisture, porosity, temperature and oxygen can be controlled for rapid and uniform decomposition.

http://www.bworganics.com/

Odors

- Odor Avoidance:
  - Maintain proper moisture and aeration to avoid anaerobic compounds (e.g. hydrogen sulfide, dimethyl sulfide, volatile fatty acids, etc.)
    - Generally there will be anaerobic pockets but as air comes in contact with aerobic organisms, odorants will be degraded.
  - Make sure incoming materials are stored properly and composted quickly to maintain aerobic conditions
  - Maintain near neutral pH or add extra carbon to avoid ammonia volatilization at higher pH's
    - This can occur in both aerobic and anaerobic conditions
  - Schedule odor causing activities (e.g., moving raw materials) in early morning and when wind direction is favorable.
- When odors do occur they should be treated.

Odor Treatment

- Air in entire enclosure is captured and treated or can be diluted and exhausted to the atmosphere
  - Want to design system so as little air as possible needs to be treated
- Depends on quality and quantity of air to be treated, results of air dispersion modeling and proximity to occupied dwellings.
- Odor Treatment Options:
  - Biofiltration
  - Chemical scrubbing
  - Thermal oxidation
  - Non-thermal plasma oxidation
  - High-carbon wood ash incorporation

Biofilters

- Use moist organic materials (e.g., compost, soil, peat, wood chips, sometimes blended with inert materials such as gravel for porosity) to adsorb and then biologically degrade odorous compounds
  - Works similar to a compost pile
- Cooled and humidified compost process air is typically injected through a grid of perforated pipes into a bed of filtration media.
- They have been shown to be effective at treating essentially all odorous compounds from composting (e.g., ammonia and volatile organic compounds)
- However, it is important to recognize that biofilters can be a source of odor themselves, if not properly maintained.

Leachate

- "the liquid that results when water comes in contact with a solid and extracts material, either dissolved or suspended, from the solid" [*On-Farm Composting Handbook*, ed. R. Rynk, 1992].
- The leachate produced in in-vessel systems can often be collected easily using options built into the system.
- It can then be used to:
  - Rewet active compost, returning nutrients to the next compost batch
  - Rewet the biofilter
  - Or is sometimes marketed as a separate fertilizer product
- It can also be disposed through:
  - The local waste water treatment system, either by truck or pipeline.
  - An engineered wetland designed to purify the leachate at the facility
  - Or, other engineered natural purification systems (e.g., filter fields).

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